PCT/GB 2004 / 003140

The Patent Office

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

REC'D 17 AUG 2004
WIPO PCT

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

I also certify that the attached copy of the request for grant of a Patent (Form 1/77) bears an amendment, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed Stephen Hordley

Dated 11 August 2004

Patents Form 1/77

Patents Act 1977
(Rule 16)

The Patent Office

THE PATENT OFFICE
D
29 APR 2004
NEWPORT

29APR04 E892311-1 D02973
P01/7700 0.00-0409547.7 NONE

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

1. Your reference — P102626GB2

2. Patent application number *(The Patent Office will fill this part in)* — 0409547.7 — 29 APR 2004

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

David Richard Hallam
80 Sandy Lane
Leyland
Preston
Lancashire PR5 1EE
United Kingdom

Patents ADP number *(if you know it)* — 7818081001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — Air cleaning device and method

5. Name of your agent *(if you have one)* — ~~Harrison Goddard Foote~~ Cruikshank & Fairweather

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

~~Orlando House~~
~~11c Compstall Road~~
~~Marple Bridge~~
~~Stockport SK6 5HH~~
~~United Kingdom~~

19 Royal Exchange Square
GLASGOW
G1 3AE.

Patents ADP number *(if you know it)* — 00014571002

FS1/77 ES
A/L 4/8/04

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

Number of earlier UK application	Date of filing *(day / month / year)*

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? — No

Answer YES if:

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.

Otherwise answer NO (See note d)

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	-
Description	37
Claim(s)	3
Abstract	-
Drawing(s)	4 + 4

9

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	-
Request for a preliminary examination and search (Patents Form 9/77)	-
Request for a substantive examination (Patents Form 10/77)	-
Any other documents (please specify)	1 Covering letter

11. I/We request the grant of a patent on the basis of this application.

Signature(s) Harrison Goddard Foote
Harrison Goddard Foote
Date 28/04/04

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom David Garnett 0161 427 7005

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.

b) Write your answers in capital letters using black ink or you may type them.

c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.

d) If you have answered YES in part 8, a Patents Form 7/77 will need to be filed.

e) Once you have filled in the form you must remember to sign and date it.

f) Part 7 should only be completed when a divisional application is being made under section 15(4), or when an application is being made under section 8(3), 12(6) or 37(4) following an entitlement dispute. By completing part 7 you are requesting that this application takes the same filing date as an earlier UK application. If you want the new application to have the same priority date(s) as the earlier UK application, you should also complete part 6 with the priority details.

Air cleaning device and method

Field of the invention

The present invention relates to an apparatus and method for the removal of impurities such as micro-organisms, smoke particles or odours from air by means of transient exposure of the air to a low power corona discharge field.

Background to the Invention

The use of ozone in many applications involving sterilising and cleaning air is well-known. Ozone generating devices have been designed for a great variety of domestic and industrial applications. All depend on ozone's great oxidising potential to kill micro-organisms and oxidise other organic particles and materials. Depending on the application, ozone is generated by means of ultraviolet radiation or electrical discharge to convert atmospheric oxygen to triatomic ozone, which can be highly effective at destroying organic atmospheric contaminants. Ozone is, however, highly toxic at high concentrations and it is increasingly clear that even at much lower concentrations it is irritant, being particularly linked with asthmatic complaints in those chronically exposed to it. In many territories there are strict statutory limits on the concentration of ozone to which members of the public and employees at a place of work may be exposed. In the UK, the Health and Safety Executive recommendation (EH38) is that the exposure limit to ozone should be 0.1 ppm (0.2 mg m^{-3}) as an 8-hour time-weighted average concentration, with a short-term exposure limit of 0.3 ppm (0.6 mg m^{-3}) as a 15-minute time-weighted average concentration.

Although undoubtedly effective at high concentrations, there is considerable evidence that ozone is ineffective as a biocide or in oxidising organic contaminants at concentrations that are safe for chronic human exposure (Dyas et al, 1983, J Clin Pathol 36: 1102–1104; Berrington and Pedlar, 1998, J Hosp Infect 40: 61–65; Esswein et al, 1994, Appl Occup Environ Hygiene 9: 139–146).

Such effect as it has in reducing odours is, in many cases, probably a mere masking with its own characteristic smell.

Alternative approaches to removing micro-organisms and other small airborne organic particles, such as smoke, obviously include direct filtration of the air. Various type of filter including so-called High Efficiency Particulate Air (HEPA) filters (defined as removing 99.97% of particles of 0.3 micron size) and HAF (High Airflow, electrete) filters capable of similar performance at higher airflows are commonly used. Although effective in some situations, such filters suffer from the disadvantages that trapped (and potentially infective) material remains on the filters, necessitating frequent changes of filter and remaining a hazard until the filters are replaced. This is a particular problem where the air being filtered is humid. In addition, such filters are incapable of removing small viral particles.

There remains a need for an efficient means of removing organic particles, micro-organisms and odours from air without release of potentially hazardous levels of ozone into an enclosed environment.

Summary of the invention

The current invention concerns a method of using a low power corona discharge field to effectively sterilise air of micro-organisms or oxidise organic airborne contaminants and particles in such a way that the air is only transiently exposed to high concentrations of ozone and is returned to the environment with the level of ozone reduced to acceptable levels for safe exposure of those living or working in the immediate environment. Preferably the concentration of ozone expelled from the apparatus is less than 0.3 ppm. Preferably, it is less than 0.2 ppm and more preferably less than 0.1 ppm.

It has been found that by means of a suitable low power corona discharge field system within a partially confined volume and drawing a suitable flow of air through said volume, preferably also incorporating one or more filters on the inlet(s) through which the flow of contaminated air is drawn and/or one or more filters on the outlet(s) through which the treated air is expelled, very high efficiencies of oxidation / sterilisation may be achieved very quickly and with a surprisingly low level of residual ozone emitted.

The apparatus of the invention comprises a means of generating ozone by means of a low power corona discharge field in such a way that it is generated and retained substantially within a confined field.

In this context 'field' means a restricted volume surrounding the low power corona discharge field device. In general, this field is contained within a partially closed containment means such a box, cabinet or casing. It is 'partially closed' in the sense that requires apertures capable of acting as one or more inlet(s) and one or more outlet(s) for a through flow of air that is produced by a suitable means, most conveniently an electrically-driven fan so arranged as to efficiently draw air in through the inlets, through the apparatus and out though the outlets.

As defined herein, 'low power corona discharge unit' means a corona discharge unit that operates at a voltage of less than 10kV and consumes less than 10W.

The ozone generating means may, in principle, be any of the mechanisms well-known in the art. Ozone is produced as a result electrochemical reactions or of the action of ultraviolet radiation, laser radiation or (most commonly and efficiently) of an electrical discharge on atmospheric oxygen. A very great number of these are known in the scientific and patent prior art (for a review of the patented devices see Miller *et al* "A history of patented methods of ozone production from 1897 to 1997", Valdosta State University, Georgia, USA at www.valdosta.edu/~tmanning/research/ozone/).

In a preferred embodiment, ozone is generated by means of a low power corona discharge device. In a highly preferred embodiment, this comprises tubular stainless steel gauze electrodes separated by a silica glass dielectric. The purpose of gauze electrodes is to maximise the surface available for the corona discharge and hence generation of ozone and other reactive species. However, other factors, such as the effects on the electromagnetic field generated, particularly hysteresis effects relating to the generation and collapse of the field during the 50Hz cycle of the alternating current, also influence the choice of gauze and the fineness of the mesh. In a preferred embodiment the gauze on the outer electrode is coarser than that of the inner electrode as this favours the production of ozone on the outer, rather than inner, electrode. In a more preferred embodiment, the mesh count of the inner electrode is between 50 to 30 x 45 to 25 (per inch or 25.4 mm) and that of the outer electrode is 35 to 20 x 40 to 20. In a particularly favoured embodiment, the mesh count of the inner electrode is 40 x 34 (per inch or 25.4 mm) and that of the outer electrode is 24 x 28.

Preferably the glass is tubular with a wall thickness of between approximately 0.70mm and 1.75mm, and more preferably between 0.8 and 1.1 mm, in order to withstand the stresses of the discharges and to have suitable dielectric qualities. It is also advantageous if the glass is a high quality quartz silicate or borosilicate with added titanium dioxide.

Power to provide a suitable ozone-generating corona discharge is provided by a transformer providing a high-voltage alternating current. In a preferred embodiment the corona discharge device runs very efficiently at a relatively low power. The voltage is preferably between 3 and 5kV, more preferably approximately 4 kV at about 1mA, so that the corona discharge unit consumes between about 3 and 5W, preferably about 4W.

Ozone generation occurs during the negative half cycle of the alternating current, at each electrode in turn. During the corresponding positive half cycle there is a tendency for resident ozone to be broken down, but this is a slower process than generation, and in any case the flow of air removes ozone from the corona discharge area as it is formed. This leads to a net production of ozone. The electrochemistry of such methods of ozone production is known in the art.

Ozone thus generated spontaneously breaks down. The half-life in air is temperature- and concentration-dependent but is in the order of days. However, this half-life is significantly shortened by humidity and by the presence of oxidisable substrates, solid surfaces and specific catalysts. In the presence of a complex arrangement of such "wall effects" and other catalytic factors the actual rate of ozone decomposition is largely unpredictable. The generation of ozone in this way in a confined field, in such a way that it rapidly decomposes beyond the field is referred to by the applicants as "closed coupled-field" generation technology.

It should be noted that, although corona discharge is a convenient method of generating ozone, a number of other highly reactive oxygen and nitrogen species are also generated. The presence of these excited molecules and the generation of further reactive products by their inter-reactions contributes to a complex 'oxidising field' surrounding the alternating current corona discharge tube of the invention.

Air is drawn through the apparatus by means of one or more electrically-driven fans, which may be conveniently mounted within the containment means, preferably at the one or more inlets to produce an efficient throughput of air. The rate of air-flow through the apparatus is not critical, but in a preferred embodiment is of the order of between 50 and 500 m^3h^{-1}. More preferably it is in the order of 150 to 500 m^3h^{-1}. For applications where a greater air-flow is

required, it will be appreciated that further fans may be fitted and a greater number and area of inlets provided.

Situations in which the anti-microbial applications of the invention are especially useful include hospitals, food preparation areas, laboratories and locations with limited ventilation, where air may be re-circulated. Storage of sterile instruments and materials in an atmosphere sterilised by means of the invention may extend their shelf life, with considerable consequent savings. The invention provides a means of supplying a unit for such storage with sterile, dry air capable of maintaining the sterility of stored instruments for extended periods. One particularly useful application is in flood-damaged buildings, where removal of fungal spores from the air can minimise subsequent growth of mould and development of rot in the fabric of the building, with significant reduction in damage and costs of repair.

In one embodiment, the apparatus is installed in ducting or pipework carrying a flow of air. In such situations, the containment means may comprise the internal surfaces of the walls of the ducting, the filters and ozone field being so arranged that all, or a significant part, of the airflow passing through the duct is filtered and transiently exposed to a low power corona discharge field, containing microbicidal concentrations of ozone. One preferred embodiment is installed in an air-conditioning system, more preferably in an air-conditioning system in an aircraft. In such applications, the apparatus efficiently removes not only infectious air-borne micro-organisms but unpleasant odours and smoke particles. This is particularly useful in passenger aircraft, ships or submarines, where a limited volume of air may be re-circulated multiple times.

In situations where the main use of the apparatus is the removal of smoke particles, it is preferred that the burden of particles passing into the ozone field is reduced by the presence of a pre-filter on the inlets to the containment means surrounding the ozone field. Where the apparatus is used to remove micro-

organisms from air that is largely free of high levels of other contaminants, the preferred configuration is the provision of a post-filter on the outlet of the apparatus. In a preferred embodiment this post-filter is an electrostatic filter.

Electrostatic filters are well-known in the art. In principle, they use charged filter media to trap charged particles. Most small units are passive in that they use the friction due to the passage of air through the filter to generate a static charge on specialised materials, which is the principle of the well-known HEPA filters. More recently, permanently polarised 'electret' filter media (Myers & Arnold, Winter 2003, International Nonwovens Journal; International patent application WO 00/01737) have formed the basis of HAF filters, which have far greater face speeds whilst maintaining highly efficient filtering of very small particles (down to 0.1μ). Large industrial electrostatic precipitators (or 'electronic' filters) use charged plates or a corona discharge to actively impart charge to airborne particles.

Without being bound by any particular theory or model, it is possible that the combination of the ozone generating low power corona discharge field unit as described, combined with an electrostatic post-filter may provide a particular synergistic benefit, with the filter materials, optionally including surface active materials such as activated charcoal and further optionally including trapped organic material, providing extra catalytic surfaces promoting decomposition of ozone and other reactive species.

Accordingly, the invention provides an apparatus for the cleaning of air comprising; a means of generating and retaining ozone and other reactive species within a confined field and a means of drawing a flow of air through said field, wherein said field comprises a concentration of ozone and/or other reactive species sufficient to effectively oxidise airborne organic material but wherein the concentration of ozone in the cleaned air expelled from said apparatus is within safe limits for a confined environment. Preferably the concentration of ozone in

the air expelled from the apparatus is less than 0.3 ppm, more preferably less than 0.2 ppm, most preferably less than 0.1 ppm. An important consideration is the accumulation of ozone in the area surrounding the apparatus during operation. Preferably the concentration of ozone1 metre from the apparatus after 15 minutes of operation is less than 0.3 ppm, more preferably less than 0.2 ppm, most preferably less than 0.1 ppm.

In one preferred embodiment, ozone is generated by means of a low power corona discharge unit, preferably one that comprises tubular metal gauze electrodes separated by a silica glass dielectric, preferably a borosilicate glass dielectric. More preferably, the silica or borosilicate glass contains a proportion of titanium. In a highly preferred embodiment, the corona discharge unit runs at a voltage of less than 5kV and consumes less than 10W. Preferably it consumes less than 6W, more preferably in the range 3W to 5W.

It is also preferred that apparatus comprises a low power corona discharge unit that is confined within a partially closed containment means. Further preferably said containment means has at least one defined inlet and at least one defined outlet to allow a through flow of air.

In a most preferred embodiment said inlets and/or outlets are fitted with one or more filters. For many applications it is preferable that the containment means comprise is comprised of metal suitable to suppress radio frequency interference resulting from the corona discharge and is suitably earthed.

In one aspect of the invention, the apparatus is one wherein air is cleaned of micro-organisms. Preferably said apparatus comprises one or more outlets that are fitted with one or more filters, more preferably electrostatic filters, most preferably electrete (HAF) filters.

In another aspect, the invention provides a method of cleaning air comprising generating and retaining ozone and other reactive species within a confined field, wherein said field comprises a concentration of ozone or other reactive species sufficient to effectively oxidise airborne organic material and drawing a flow of air through said field, such that the cleaned air having passed through said field contains a concentration of ozone that is within safe limits for a confined environment, preferably less than 0.3 ppm, more preferably 0.2 ppm, most preferably 0.1 ppm.

In a highly preferred embodiment ozone or other reactive species are generated by means of a low power corona discharge unit.

Preferably said method comprises passing the air through at least one filter after exposure to ozone. More preferably, said filter is fitted to the outlet and catalyses the decomposition of ozone to diatomic oxygen.

In one preferred embodiment, air is cleared of viable airborne micro-organisms and passes through a filter after exposure to low power corona discharge field. More preferably, this filter is an electrostatic filter.

The invention also provides a method of increasing the usefulness of filters, particularly filters designed to remove airborne micro-organisms. Such filters require to be replaced or cleaned as organic particles and / or micro-organisms are deposited on them. Where such filters are also bathed in ozone-enriched air, this has the effect of oxidising such trapped organic particles and micro-organisms with the result that the effective life of the filter is increased and micro-organisms destroyed. The corollary of this effect is any remaining ozone passing through the filter is efficiently broken down as it oxidises the organic material trapped there. This effect is increased by the intrinsic catalytic effect of filter components on the decomposition of ozone. In this way, the combination of highly efficient filters, such as HEPA or HAF electrostatic filters capable of

effectively removing particles as small as 0.1 to 0.3 microns, and bacteriacidal concentrations of ozone in the air being filtered is synergistic, with an increased benefit over that obtained over either alone, in terms of prolonged efficient filtering and killing of potentially infectious micro-organisms.

In a further aspect of the invention, the apparatus is one wherein air is cleaned of smoke particles. Preferably, said apparatus comprises one or more inlets that are fitted with one or more filters. In one preferred embodiment, air is drawn in through one area of a filter assembly and expelled though a second area of the same filter assembly. Preferably, the filter assembly comprises two or more filter elements, more preferably, at least one the elements is an electrostatic filter.

Also provided is method of cleaning air comprising generating and retaining ozone within a confined field, wherein said field comprises a concentration of ozone or other reactive species sufficient to effectively oxidise airborne organic material and drawing a flow of air through said field, such that the cleaned air having passed through said field contains a concentration of ozone that is within safe limits for a confined environment, wherein air is cleared of smoke particles and wherein air passes through a filter before exposure to ozone.

Detailed description of the invention

The invention will now be described in detail, with reference to the following examples and drawings.

Figure 1 shows a schematic cross-section of an apparatus for the removal of micro-organisms from air according to the invention. 1 indicates the casing, 2 the inlet, 3 the fan, 4 an optional pre-filter, 5 the transformer, 6 the corona discharge unit, 7 the outlet, 8 the electrostatic post-filter.

Figure 2 shows the construction of the corona discharge ozone-generating unit. 1 is the glass tube dielectric, 2 the outer mesh electrode, 3 the inner mesh electrode fitted with a spade end electrical connector (4). When constructed the outer mesh is rolled into a tube with a flange (5) providing a fixing means. 6 is an insulating plastic plate locating the assembly by means of insulating screws (7) nuts and washers (8).

Figure 3 shows a perspective view of one embodiment of the invention showing a casing for a model with four apertures for fans.

Figure 4 illustrates the use of a single filter assembly in a four-fan (P8) device to provide both pre- and post-filtering. This configuration is especially useful for removal of smoke. The unit comprises a force chamber partially contained by casing (1), fitted with a filter cover (2) by which is attached a first filter (3). In this example this is a 3M low pressure 3202WAT Filtrete™ tobacco filter. Inside this is a second filter, in this case a 3M Filtrete™ HAF filter. The force chamber contains two fans, configured such that one draws air into the unit and the other expels it. As a result, the smoke laden air is first drawn through one area of the the two filter layers into the unit, passes through the low power corona discharge field and then exits through a second area of the two filter layers.

Example 1. Apparatus for the removal of micro-organisms from air

<u>Construction</u>

With reference to Figure 1, the apparatus comprises a containment means consisting of a casing (1), in this case of thin sheet metal construction. This casing has an inlet (2) fitted with an electrically-driven fan (3) so positioned as to produce an efficient flow of air into the apparatus. The inlet may, optionally, have a pre-filter (4) fitted. Within the casing is an approximately 4W corona discharge unit (6) operating at approximately 4kV and 1mA. A transformer (5) supplies

power to the corona discharge unit. In this case the outlet (7) is fitted with an electrostatic post-filter (8, HAF, Filtrete™ 3M Corporation)

The details of the construction of the corona discharge unit are shown in Figure 2. A silica glass tube dielectric (1) with a wall thickness of 0.8–1.1mm has outer (2) and inner (3) essentially tubular stainless steel gauze electrodes. The dimensions are not critical but in this case the glass tube is approximately 63 mm long, inner electrode is formed from a 40 x 34 mesh number gauze of approximately 71 x 63mm, and the outer electrode is formed from a coarser 24 x 28 mesh number gauze of approximately 133 x 63mm. The inner electrode fits within the glass tube and is fitted with a spade end electrical connector (4). The outer electrode is formed into a cylinder fitting around the glass tube with a flange (5) allowing it to be fixed, together with the glass tube and inner electrode assembly, to a suitable insulating plastic base plate (6) by means of insulating nylon screws (7) and washers and nuts (8).

Figure 3 shows a casing suitable for use as a containment means, as described above. By configuring fans appropriately, air may by drawn in through the louvred apertures and out through the circular apertures, optionally though a post-filter. This arrangement is particularly suitable for use in an apparatus for the removal of micro-organisms from air.

Performance

This unit has been tested for efficiency in microbiological tests for killing of airborne bacteria and fungal (*Aspergillus niger*) spores and found to kill >95% at a flow rate of about 150 m^3h^{-1}.

The output of ozone has also been tested and been found to be within the EH38 guidelines.

Example 2. Anti-microbial performance of an M4/4 device

The invention has been developed into a range of devices designed for microbiological decontamination of atmospheres. This embodiment employs closed-coupled field technology for the contained generation of an oxidising field, in tandem with electrostatic filtration of the air stream. Combining these technologies in a manner that affords a high flow-rate permits the effective treatment of large volumes of atmosphere.

<u>M4/4 device</u>

This embodiment of the invention comprises four fans connected and switched so as to be progressively activated in order to provide a range of airflow rates:

Speed 1 = 160 m^3/hour
Speed 2 = 320m^3/hour
Speed 3 = 480 m^3/hour
Speed 4 = 540 m^3/hour

Two modes of filtration were used in various experiments. Either a HEPA filter or an HAF (3M Filtrete™) post-filter were fitted and their relative effects compared.

<u>Ozone production characteristics</u>

The European standard for atmospheric levels of ozone is currently 0.2 ppm while, according to various literature sources the required dosage of ozone required to inactivate microbial systems, on contact, varies between 0.05 ppm and 0.4 ppm.

An important aspect of this validation effort has been to demonstrate compliance of the device with European ozone emission standards, whilst additionally producing evidence of sufficient ozone generation to accommodate effective competence with regard to the task of broad scope anti-microbial activity.

A key advantage of the device is the claim that ozone generation and reactions with micro-organisms, occur contained solely within the device resulting in decontamination with no measurable emission of ozone.

Ozone measurements

Ozone levels have been investigated employing a novel probe by which ozone production is determined by measurement of the degree of oxidation obtained with a d-α tocopherol coating during exposure. Trials have been conducted to measure ozone production within the device and the potential for environmental accumulation during use, with and without filter *in situ*.

Table 1: Measurement of ozone production by d-α tocopherol probe oxidation with filter in place

Run Time hours	0^3 ppm within treatment chamber	0^3 ppm within 60 m^3 Room
0	24	<0.2
6	103	<0.2
12	94	<0.2
18	107	<0.2
24	102	<0.2

Table 2: Measurement of ozone production by d-α tocopherol probe oxidation without filter in place

Time hours	O_3 ppm within treatment chamber	O_3 ppm within 60 m^3 Room
0	41	<0.2
6	96	<0.2
12	97	<0.2
18	104	<0.2
24	106	<0.2

Data indicate no significant emission of ozone from the device were detected over a 24 hour period in the operating environment. Measurements indicate that significantly higher levels of ozone are produced within the closed coupled field

device than predictably are required for contact inactivation all classes of micro-organisms for which susceptibility has been published.

Microbiological aspects of filter performance

Electrostatic air filtration is known to produce reduction in the levels air-borne microbial contaminants. A potential problem with stand-alone filtration devices is therefore the accumulation of possibly infective or otherwise unwanted viable contamination within the structure of the filter during life span. Trials conducted to monitor these possibilities generated the following data showing the recovery of differing classes of organism from the interior surfaces of the terminal filter during different periods of operation in waste processing room.

Table 3: Recovery of viable micro-organisms from electrostatic filter material after differing periods of usage

Operation interval	TVC cm^3 Filter material	Moulds cm^3 Filter material	Yeasts cm^3 Filter material	*Bacillus* sp. cm^3 Filter material	Gram neg sp. cm^3 Filter material	Gram Pos sp. cm^3 Filter material
1 day	<10	<10	<10	<10	<10	<10
1 week	<10	<10	<10	<10	<10	<10
1 month	<10	<10	<10	<10	<10	<10
4 months	<10	30	<10	20	<10	80

Conclusions

These data demonstrate that in an environment known to have high levels of air-borne microbial contamination significant build up of viable organisms occurred in the filtration unit up to and including three months of use. This effect may caused by impingement of residual zone on the active surfaces, loss of viability due to dehydration in the high flow rate of air, nutrient scarcity or a combination of these and other factors.

Such findings to some degree support the anti-microbial efficiency of the ozone generation system presented. More importantly these findings suggest that in

respect of bacteria and fungi the filtration stage is unlikely to represent a biological hazard during replacement.

Example 3: Single pass anti-microbial competence of M4/4 device

The following experimental data reports on the performance of the device in relation to the reduction of single pass microbial challenges. Performance at each of four flow rates has been determined for a range of organisms with and without electrostatic filtration in place.

Table 4: M4/4 single pass performance with electrostatic filtration

Organism	Challenge level cfu/l-^{1}	Speed 1 Recovery cfu/l-1	Speed 2 Recovery cfu/l-1	Speed 3 Recovery cfu/l-1	Speed 4 Recovery cfu/l-1
A.niger	8.80E+06	<1	<1	<1	<1
S.typhimurium	7.40E+06	<1	<1	<1	<1
C.albicans	6.00E+06	<1	<1	<1	<1
S.aureus	7.10E+06	<1	<1	<1	<1
B.cereus	2.20E+06	<1	<1	<1	1.30E+02

Table 5: M4/4 Single performance with no electrostatic filtration

Organism	Challenge level cfu/l-^{1}	Speed 1 Recovery cfu/l-1	Speed 2 Recovery cfu/l-1	Speed 3 Recovery cfu/l-1	Speed 4 Recovery cfu/l-1
A.niger	7.00E+06	<1	<1	<1	<1
S.typhimurium	8.40E+06	<1	<1	<1	<1
C.albicans	8.30E+06	<1	<1	<1	<1
S.aureus	9.20E+06	<1	<1	<1	<1
B.cereus	4.70E+06	<1	<1	3.10E+02	9.80E+02

Speed 1 = 160 m^3/hour
Speed 2= 320m^3/hour
Speed 3= 480 m^3/hour
Speed 4= 540 m^3/hour

Conclusions

All conditions of treatment produced significant levels of reduction in the levels of air-borne challenges. Under these challenge conditions Speed 3 gave a 100 %

performance with filter in place while Speed 2 gave a 100 % performance with no filter in place. With filter in place all organisms were reduced to non-detectable levels at increment 4 with the exception of *Bacillus cereus*, where only a 4 log reduction was achieved. It was noted that limiting the flow to Speed 3 (480 m^3/hour) with the filter *in situ*, guaranteed a consistent and rapid degree of air processing.

Example 4: Single pass killing of fungal spores and hyphae

Experimental design

These experiments introduced of a number of single calibrated doses of *Aspergillus niger* hyphal fragments and spore particles into a chamber having a 8 l^{-1} volume. The chamber was constructed in a manner as to permit access of the Quest device intake grill to the interior of the chamber while the output section vented directly into a second chamber of identical volume. Both chambers were vented by membrane filters for the purpose of pressure equalisation. The purpose of the trial was to attempt to demonstrate a single pass efficiency in lethality in a known airborne pathogen.

Dosing conditions

The biological material was delivered in the form of fungal hyphae and spores dispersed in calcium silicate matrix. Both chambers were equipped with fans intended to assist dispersion. Sampling was conducted via suction with collection in a 2 % sucrose/saline solution an involved 2 L^{-1} volume for each chamber. The device was not operational during dosing for 2 minutes after the introduction of the biological material but had been previously stabilised for 30 minutes. After the post-dose period the device was operated for period of 1 minute and after which the atmosphere in the delivery chamber was sampled.

Analysis

Recovery solutions were examined by serial dilution and survivors were estimated on oxytetracycline glucose yeast agar (5 days at 25°C). The results of these counts provided estimates of the level of dosage and the level of survivors per l^{-1} of atmosphere before and after treatment.

Results

Tables 6 and 7 present the data obtained in this trial for instances of the device operating with either the electrostatic or HEPA filter in place.

Table 6: Single pass efficiency for *Aspergillus niger* (mixed hyphae and spores) employing Electrostatic filtration and 0_3 dosing

Challenge level cfu/l^{-1}/air pre in take	Recovery level cfu/l^{-1}/air post filter	Percentage Kill
8.3E+05	7.6E+04	90.807
4.2E+05	2.0E+03	99.524
6.1E+05	4.1E+03	99.328
7.3E+05	9.2E+03	98.740
7.2E+05	6.2E+03	99.139
7.4E+05	7.1E+03	99.041
8.2E+05	8.4E+03	98.976
6.3E+05	9.2E+03	98.540

Mean	98.012

Table 7: Single pass efficiency for *Aspergillus niger* (mixed hyphae and spores) employing HEPA filtration and 0_3 dosing

Challenge level cfu/l^{-1}/air pre in take	Recovery level cfu/l^{-1}/air post filter	Percentage Kill
5.5E+05	8.0E+01	99.985
6.1E+05	9.0E+01	99.985
2.8E+05	3.0E+01	99.989
6.1E+05	9.0E+01	99.985
6.3E+05	8.0E+01	99.987
5.2E+05	8.0E+01	99.985

6.3E+05	1.1E+02	99.983
5.8E+05	5.0E+01	99.991
	Mean	99.986

Example 5: Continuous dosage lethality with a range of micro-organisms

In this series of trials a wide range of microbial types was continuously introduced at the intake section of the M4/4 device for a period of 1 hour. During the exposure time periodic measurements were taken at the output section and the levels of survivors determined. The following results were obtained.

Table 8: M4/4 performance: continuous input of bacteria and fungi

Organism	Class	Mean cfu/m^3/Hr at input Treatment stream	Mean cfu/m^3/Hr post Treatment exit stream	Mean decline Log/cfu/m^3/Hr post Treatment exit stream	Apparent percentage reduction
Escherichia coli	Gram –ve	2.1E+05	0.0E+00	>5	>99.999
S.tyhpi murium	Gram –ve	4.6E+05	0.0E+00	>5	>99.999
E.agglormerans	Gram –ve	3.9E+05	0.0E+00	>5	>99.999
E.gergoviae	Gram –ve	4.2E+05	0.0E+00	>5	>99.999
A.aerogens	Gram –ve	7.1E+05	0.0E+00	>5	>99.999
S.marcescens	Gram –ve	8.2E+05	0.0E+00	>5	>99.999
E.sakazakii	Gram –ve	3.4E+05	0.0E+00	>5	>99.999
E coli 0157 H:7	Gram –ve	3.5E+05	0.0E+00	>5	>99.999
P.aeruginosa	Gram –ve	6.1E+05	0.0E+00	>5	>99.999
P.putida	Gram –ve	8.2E+05	0.0E+00	>5	>99.999
S.aureus oxford	Gram +ve	4.3E+05	0.0E+00	>5	>99.999
S.aureus MSRA	Gram +ve	4.8E+05	0.0E+00	>5	>99.999
S.epidermidis	Gram +ve	3.7E+05	0.0E+00	>5	>99.999
M.luteus	Gram +ve	9.0E+05	0.0E+00	>5	>99.999
S.faecalis	Gram +ve	7.3E+05	0.0E+00	>5	>99.999
S.pyogenes	Gram +ve	3.6E+05	0.0E+00	>5	>99.999
B.cereus	Gram +ve	7.1E+05	0.0E+00	>5	>99.999
B.globigii	G+ve Spore	7.9E+05	1.0E+01	>5	99.999
B.subtilis	G+ve Spore	2.1E+05	3.0E+01	>5	99.986
B. megaterium	G+ve Spore	6.2E+05	9.0E+01	>5	99.985
S.cerevisiea	Yeast	4.3E+05	0.0E+00	>5	>99.999
S.bailli	Yeast	7.2E+05	0.0E+00	>5	>99.999
Pichia mixed sps	Yeast	6.3E+05	0.0E+00	>5	>99.999
S.ludwigii	Yeast	6.0E+05	0.0E+00	>5	>99.999
A.niger	Mould mycelial	6.2E+05	0.0E+00	>5	>99.999
A.flavus	Mould mycelial	7.8E+05	0.0E+00	>5	>99.999
F.poea	Mould mycelial	7.2E+05	0.0E+00	>5	>99.999
P.digitatum	Mould mycelial	6.9E+05	0.0E+00	>5	>99.999
F graminerium	Mould mycelial	4.3E+05	0.0E+00	>5	>99.999
A.niger	Mould Spore	8.2E+05	7.0E+01	>5	99.991
A.flavus	Mould Spore	6.7E+05	5.0E+01	>5	99.993
F.poea	Mould Spore	8.2E+05	0.0E+00	>5	>99.999
P.digitatum	Mould Spore	6.7E+05	0.0E+00	>5	>99.999
F graminerium	Mould Spore	2.9E+05	0.0E+00	>5	>99.999

Table 9: M4/4 performance: continuous input of viral particles

Organism	Class	Mean cfu/m^3/Hr at input Treatment stream	Mean cfu/m^3/Hr post Treatment exit stream	Mean decline Log/cfu/m^3/Hr post Treatment exit stream	Apparent percentage reduction
CTX	SS DNA	4.3E+12	8.1E+02	>12	>99.999
ScV-L-BC	DS RNA	9.2E+12	4.6E+02	>12	>99.999
FcoV (attenuated)	SS + RNA	7.1E+12	3.0E+02	>12	>99.999
T4 Phage	DS DNA	5.3E+12	7.4E+02	>12	>99.999

Conclusions

The device demonstrated a high level of competence in the inactivation of a wide range of micro-organisms including bacterial cells, bacterial spores, viral particles, mould, mould spores and yeasts. Kill efficiencies in excess of Log 12 were obtained consistently for all classes of viral particle examined, while for all other classes of organism no less than a Log 5 kill was obtained on a continuous basis. In summary, the device is highly effective at killing micro-organisms.

Example 6: Sanitisation of a laboratory incubator room

Introduction

In spite of good compliance with GLP standards laboratories may still develop problems associated with airborne microbial contamination. Usually such problems are detected by routine environmental surveillance or incidences of contamination on solid agar plates.

In this study a problem was investigated relating to a persistent environmental contamination in a commercial grain testing laboratory. This facility had reported significant levels of mould contamination of both blank plates and plates intended for the isolation of yeasts and moulds from samples. In-house environmental analysis by settle plate determined the presence of identical isolates to those found on the plates in the atmosphere of the incubation room. The isolate

responsible for the contamination was confirmed as *Fusarium poae*. This organism is common in temperate regions and is associated with commodities such as wheat and maize, both of which were commonly handled by the facility. It demonstrates growth over the range 2.5°–33°C and, characteristically, produces profuse growth with salmon or pale pink colonies on common mycological media.

<u>Trial outline</u>

The trial was conducted in two stages. During the first month of monitoring the M4 device was not in operation and air sampling was conducted on an hourly basis between the hours of 9.00am and 6.00 pm over a six-day working week. Sampling was conducted employing a Cassela volumetric sampler with impaction onto oxytetracycline glucose yeast agar. During week one (device off) 0.1, 0.2, and 0.5 L^{-1} air volumes were taken at the specified intervals.

The device was operative during month two. Sampling was conducted to the same schedule described above with an identical sampling procedure. Simultaneously, during the trial records were kept of non-compliant contaminated agar intended for use in analytical procedures.

<u>Results</u>

Table 10: Mean air quality in a laboratory incubation area and media quality over a two-month period with and without the M4 device in operation.

Device status	Week	F. poae cfu/L^{-1}/Air	Percentage in lab plate contamination
OFF	1	17100	3
OFF	2	21300	2
OFF	3	16700	9
OFF	4	18900	3
	Mean	18500	4.25
ON	5	20	<1
ON	6	40	<1
ON	7	2	<1
ON	8	3	<1
	Mean	16.25	<1

Conclusions

In this laboratory an overt problem had been experienced in relation to media contamination which was directly related to environmental cross-contamination with *Fusarium poae*._The operation of the M4/4 device in the area that was the source of this problem successfully reduced the level of contamination on a consistent basis by between 2 and 3 log cycles L^{-1} air. This magnitude of effect was sufficient to reduce the level of media contamination to a non-detectable level. On this basis, the M4/4 device has been shown to be an effective tool in the maintenance of a microbiological laboratory air quality.

Example 7: Sanitisation of the atmosphere in a Class II microbiological laboratory waste room.

Introduction

A device according to the invention with a free fan transfer volume of 190 m^3/hour fitted with either replaceable electrostatic (flow rate = 160 m^3/hour) or HEPA (flow rate = 65 m^3/hour) post-filters was subjected to a practical evaluation in a Class II microbiological laboratory waste room.

It was theorised that usage of electrostatic filtration in combination with a closed coupled filed oxidation field would afford both reduction of airborne micro-organisms as well as good odour decontamination characteristics while employment of HEPA filtration was anticipated to produce superior microbiological performance. Assessment was by monitoring the reduction of airborne Gram-negative bacteria over a seven day period in a microbiological laboratory waste-processing room. Measurement included the performance characteristics of both filtration systems.

The vast majority of contemporary microbiological laboratories are equipped with a designated area designed to afford physical segregation of contaminated biological waste intended for sanitation by autoclaving preceding safe disposal. Such waste consists of agar plates, cultures and implements employed in

microbiological manipulations. In general, such waste is extremely biologically active prior to treatment and may contain billions of organisms per gram. While every effort in GLP is to prevent transfer of contaminants, the nature of the autoclaving process requires that storage bags are open to the atmosphere at the start of processing. As a consequence, the opportunity exists for the introduction of large masses of organisms or spores into the environment. Factually, such areas exhibit high levels of airborne contamination.

These distribution factors coupled with the thermal currents created by autoclave operation engender a demonstrably abundant and sustained level of airborne micro-organisms of many differing types. It is true that such contamination is unlikely to present as a direct health risk through inhalation but such an environment provides a useful model for efficiency studies of devices, which purport to reduce airborne levels of micro-organisms.

In this trial, the regime involved the sampling of the atmosphere in the test environment by impaction of air onto the surface of agar plates through the use of a Cassela air-sampling device. The Cassela unit is capable of accurately sampling a known volume of atmosphere over a 30 second period and continuously delivering the sampled air to an enclosed chamber. In this chamber an agar plate is exposed to column of intake air whilst rotating, thus distributing micro-organisms evenly over the surface of the plate. Subsequent incubation of the plates allows enumeration of organisms present in the original volume of atmosphere examined. Through the use of differing types of agar and diagnostic tests, it is possible differentially count different types or classes of micro-organism.

Room Conditions

The room comprised a 24.3 m^3 cube. It contained an autoclave with treated waste in one half and 25 kg storage bags of untreated waste in the remaining floor area. At any one time the area contained a minimum of 16 untreated waste

bags, of which between 8 and 10 bags were be handled and processed in a working day between the hours of 9.00 am and 6.00 pm. The sampling device was located centrally. Normally the room atmosphere was vented by forced extraction, but this was suspended during the trial. The autoclave hot exhaust was vented via an enclosed circuit, which was not thought to affect the atmospheric composition of the test environment.

Sampling Plan

Sampling occurred over a twenty-four hour period at the intervals given in Table 11 below. Such sampling extended over a seven-day period with the device running without any form of filtration in place and without the ozone generator switched on, to demonstrate the background level of contamination. The data obtained are given in Tables 11 and 13 below. The data gathered in this exercise were employed as the comparison set for all information gathered during the subsequent period when the device was operational as a sanitising unit.

Two further identically-scheduled sampling periods were conducted sequentially separated by a four day recovery gap. Firstly, the device was operated with the corona discharge unit on and an electrostatic filter in place. In the second session the device was operated with a HEPA filter in place, again with an identical sampling plan.

Microbiological analysis

The agar employed in all tests was Violet Red bile glucose agar (VRBGA) intended for the recovery of Gram-positive organisms from the atmosphere through the use of the Cassela device. Colonies were recovered on this agar after incubation at 35° C for 24 hours. As the trials were intended primarily to show overall comparisons, it was assumed that all isolates obtained on VRBGA were Gram-negative and all isolates were counted. Colonies were further differentiated on the basis of oxidase reaction. All sampling was conducted in duplicate.

Results

Table 11 below presents the data obtained for Gram-negative (Ox +ve and Ox –ve) isolates during the unsanitised control period and that for the data obtained during the period of oxidation treatment associated with electrostatic filtration of the return air flow. Table 8 illustrates the average percentage kill through out the day attributable to the action of oxidation treatment and electrostatic filtration. Tables 9 and 10 summarise the same categories of data obtained for the period when sanitisation was attempted employing oxidation and HEPA filtration.

Table 11: Mean microbial levels over a 24 hour period in a microbiological waste room (23.4 m^3) with and without continuous operation of device with electrostatic filtration

Time	Condition	Oxidase Pos Gram negative isolates L^{-1} air	Oxidase Neg Gram negative isolates L^{-1} air
06:00 AM	O_3 off EF-	4.7E+03	8.6E+03
10:00 AM	O_3 off EF-	5.6E+03	9.2E+03
02:00 PM	O_3 off EF-	9.8E+03	2.8E+04
06:00 PM	O_3 off EF-	2.0E+04	3.7E+04
08:00 PM	O_3 off EF-	1.8E+04	3.3E+04
02:00 AM	O_3 off EF-	9.2E+03	1.9E+04
04:00 AM	O_3 off EF-	3.7E+03	8.7E+03
06:00 AM	O_3 on EF+	6.0E+02	1.3E+03
10:00 AM	O_3 on EF+	7.7E+02	1.3E+03
02:00 PM	O_3 on EF+	1.6E+03	4.4E+03
06:00 PM	O_3 on EF+	3.4E+03	6.2E+03
08:00 PM	O_3 on EF+	3.4E+03	5.8E+03
02:00 AM	O_3 on EF+	1.4E+03	3.0E+03
04:00 AM	O_3 on EF+	4.8E+02	1.2E+03

Table 12: mean microbial % reduction levels over a 24 hour period in a microbiological waste room (23.4 m^3) with device operating with electrostatic filtration

Time	Condition	Oxidase Pos Gram negative isolates L^{-1}/air	Oxidase Neg Gram negative isolates L-1/air
06:00	O_3 on EF+	87.3	85.1
10:00	O_3 on EF+	86.2	85.4
14:00	O_3 on EF+	83.2	84.3
18:00	O_3 on EF+	82.8	83.2
20:00	O_3 on EF+	81.3	82.2
02:00	O_3 on EF+	85.3	84.6
04:00	O_3 on EF+	86.9	85.8

Table 13: mean microbial levels over a 24 hour period in a microbiological waste room (23.4 m^3) with and without continuous operation of device with HEPA filtration

Time	Condition	Oxidase Pos Gram negative isolates L^{-1}/air	Oxidase Neg Gram negative isolates L-1/air
06:00	O_3 off HEPA-	4.7E+03	8.6E+03
10:00	O_3 off HEPA-	5.6E+03	9.2E+03
14:00	O_3 off HEPA-	9.8E+03	2.8E+04
18:00	O_3 off HEPA-	2.0E+04	3.7E+04
20:00	O_3 off HEPA-	1.8E+04	3.3E+04
02:00	O_3 off HEPA-	9.2E+03	1.9E+04
04:00	O_3 off HEPA-	2.1E+03	8.7E+03
06:00	O_3 On HEPA+	3.1E+03	5.7E+03
10:00	O_3 On HEPA+	3.9E+03	6.2E+03
14:00	O_3 On HEPA+	7.0E+03	2.0E+04
18:00	O_3 On HEPA+	1.6E+04	2.8E+04
20:00	O_3 On HEPA+	1.5E+04	2.7E+04
02:00	O_3 On HEPA+	6.5E+03	1.4E+04
04:00	O_3 On HEPA+	1.4E+03	5.7E+03

Table 14: mean microbial % reduction levels over a 24-hour period in a microbiological waste room (23.4 m^3) with device operating with HEPA filtration.

06:00	O_3 On HEPA+	34.5	33.9
10:00	O_3 On HEPA+	30.3	33.1
14:00	O_3 On HEPA+	28.6	28.7
18:00	O_3 On HEPA+	22.1	24.6
20:00	O_3 On HEPA+	19.2	17.4
02:00	O_3 On HEPA+	29.6	28.2
04:00.	O_3 On HEPA+	34.8	34.2

Conclusions

The data given in tables 11–14 indicate that the test environment under conditions of no treatment did exhibit elevated levels of airborne microbial contamination. In the same tables it is observed that irrespective of the filter type employed with device, measurable reduction of airborne levels of Gram negative bacteria was achieved. On a continuous use basis with active replacement of micro-organisms into the environment, operation with electrostatic filtration gave an average of 84 % reduction of gram negative bacteria (Ox +ve and -ve). This amounts to a continuos overall reduction of between 1 and 2 log cycles. By comparison the unit gave only 28 % when operated with HEPA. filtration.

In theory, HEPA filtration should provide greater efficiency with respect to microbial removal but under the trial conditions we calculated that with this form of filtration in place the device was capable of only 2.7 room changes per hour. It is apparent this was an insufficient flow rate to achieve high levels of reduction in an environment to which micro-organisms are constantly being added.

In the case of operation with electrostatic filtration, 7.1 room changes per hour were obtained, a factor which produced a much higher degree of impingement on the levels of airborne gram negative bacteria.

Both forms of filtration gave very high kill efficiencies during the single pass trials with *Aspergillus niger*. In this case HEPA in combination with ozonation gave 99.986 reduction of challenge, which is close to theoretical performance. On the other hand electrostatic filtration in combination with ozonation gave 98.012 reduction of challenge.

Overall, the data favour the combination of closed coupled filed oxidation with electrostatic filtration. This configuration affords high flow rates with very high levels of kill in an environment where recontamination of sanitised air is continuous. By comparison with other commercial units the kill rate in the waste room environment may be considered very significant.

Example 8. Odour-removing apparatus

The principle of drawing air through a field of high oxidation potential sufficient to oxidise many organic pollutants is equally applicable to the removal of unpleasant or unwanted odours, where these are caused by compounds capable of being oxidised to odourless products. The apparatus of the invention, optionally fitted with pre- and/or post-filters, preferably containing activated charcoal is highly suitable for this purpose.

<u>Trial Outline</u>
A sensory evaluation was conducted each day during operation of an M4/4 device in the microbiological waste processing facility. This involved subjective scoring by four people according to the Key given with Table 15, below.

Evaluations were made for each type of filter and with the closed coupled oxidising field operating.

Table 15: Sensory appreciation scores obtained during operation of device with either electrostatic filtration or HEPA

Day	Electrostatic	HEPA
0	1	1
1	3	2
2	6	2
3	6	3
4	6	2
5	6	3
6	6	2
7	6	3

Key to scores

1 Unpleasant
2 Change perceived but unpleasant
3 Improvement
4 Acceptable but some odour detected
5 Acceptable environment
6 Markedly improved odour free

Example 9: Apparatus for the removal of smoke particles from air

Introduction

The apparatus based in the casing shown in Figure 3 may be configured for the efficient removal of smoke from air. In this embodiment the fans may be so arranged as to draw air in through the circular apertures, preferably through a pre-filter, through the field of high ozone concentration and either out through the louvred apertures shown or back out through a post-filter arrangement.

In a preferred specific embodiment, particularly suitable for use in public areas such as public houses, hotels and bars, the apparatus employs four fans so arranged as to draw air in through one portion of a filter assembly and out through another area, as illustrated in Figure 4. This apparatus (the 'P8' model)

is configured with two fans drawing air in through the filter assembly (ie there is a pre-filter) and two fans expelling air out through the filter assembly (ie the air is also post-filtered). The capacity of the apparatus is approximately 540 m^3 per hour. The filter assembly comprises an outer low pressure 3M 3202 WAT tobacco smoke filter and an inner 3M Filtrete™ HAF electrostatic filter.

The core components of fan, closed coupled field unit and filters are common with the apparatus of Example 1.

Study design

The efficiency of the device in reduction of eight types of tobacco-related toxic substances was tested in a test environment. These substances primarily occur in the atmosphere due to combustion of tobacco and the associated exhalation of smoke from combusted tobacco. A list of the analytes determined is given in Table 17 below.

The test environment consisted of a public house pool room with a volume of 84 m^3 into which the P8 unit was installed. During the operation the device, per specification, was predicted to change and process the environment within this room at a rate 9 times per hour. Common practice prior to the trial was to evacuate the atmosphere by forced and passive ventilation. These systems of air purification were considered unsatisfactory by the proprietor of the property, especially during the winter, due to the requirement to compensate for massive heat loss.

After installation of the P8 device, air sampling was conducted in the pool room for seven days, between the hours of 8.00 pm and 9.00 pm at a rate of 5 m^3 per hour, without the device in operation. This provided background control data for all analytes. A further set of control data was obtained at 5.0 pm which represents a point after normal ventilation when the room is not used for pool or smoking. The data relating to this point may be considered base level for all

analytes. During the subsequent seven days the sampling procedure was repeated with the device in operation, with the goal of determining the efficiency of atmospheric clean up.

During the trial an estimate was made of the daily cigarette consumption during the sampling interval. Sampling was conducted by the use of a vacuum device with collection of sampled atmosphere in either phosphate buffer or an acetonitrile : methanol phase. Analytes were determined quantitatively employing the following analytical techniques : gas / liquid chromatography, HPLC diode array and differential pulse polarography.

Results

Table 16 below describes the pattern of cigarette consumption recorded for the test environment during the sampling periods. Table 17 describes the mean levels of analytes recorded during the control period and during the period of sampling when the P8 device was activated. This table also describes the contribution to air quality attributable to the device in terms of percentage reduction of airborne toxic substances.

Table 16: Mean cigarette consumption in a public house pool room between 8.00 PM and 9.00 PM

Day	Cigarette consumption per hour
Monday	5
Tuesday	11
Wednesday	7
Thursday	9
Friday	19
Saturday	23
Sunday	16
Mean	13

Table 17: Mean level of tobacco smoke analytes in the atmosphere in a public house pool room for a seven day period with and without the P8 unit in operation

ANALYTE	UNIT	Mean level 5PM No treatment	Mean level 9PM No treatment	Mean level 9PM with treatment	Mean reduction due to treatment
		Device off	Device off	Device on	
Carbon monoxide	Mg/m^3	0.82	7.1	0.4	94.4
3-ethenylpyridine	Mg/m^3	0.17	37.6	0.4	98.9
Formaldehyde	Mg/m^3	0.33	84.2	0.2	99.8
Acetaldehyde	Mg/m^3	0.01	196.3	0.4	99.8
Ammonia	Mg/m^3	0.01	103.5	0.8	99.2
Nicotine	Mg/m^3	0.96	61.4	1.06	98.3
Total phenolics	Mg/m^3	0.11	12.7	0.2	98.4
Total cresols	Mg/m^3	0.06	3.8	0.08	98.9

Discussion

The test data demonstrates that operation of the P8 device produced highly significant reduction in all levels of tobacco smoke analytes with overall analyte clearance rates over the range 97.9 to 99.8%. The level of reduction is such that the residue levels during device operation are not significantly different from background level during periods when the room was in disuse. Considering the findings and that there was virtually constant replacement of the analytes to the atmosphere, P8 device performed in a highly efficient manner in the removal of toxic tobacco smoke contaminants.

Example 10: Duct-mounted apparatus

A particularly useful application of the invention is its incorporation into air-conditioning ducting in buildings and, in particular, in aircraft. A preferred embodiment comprises a cartridge assembly, through which air flows, comprising one or more corona discharge unit as herein described, optionally with one or more filter assemblies. In this situation, the pressure within the duct may be sufficient to allow a suitable flow of air through the cartridge assembly without the further use of fans or impellors. It has been found that one 5W corona discharge unit, as described, per approximately 500 m^3 per hour throughput of air is

suitable. Such units are useful in clearing air of micro-organisms, odours, and smoke.

Example 11 Levels of ozone leakage: active and passive sampling

A: Active sampling

Tests performed

The leakage of ozone from an operating AM4 unit (190m^3 h^{-1} airflow, one 5W corona discharge unit) was measured when the air filtration system was operated in 4 different modes: (i) filter in and corona discharge unit on; (ii) filter out and corona discharge unit on; (iii) filters in and corona discharge unit off, and (iv) filters out and corona discharge unit off.

The ozone levels were measured at 0, 0.5 and 1.0 m from the emitting face of the unit. The distance was measured using a metre rule and was checked at intervals during the experiment by the operator. The experiment was performed on 19 June 2002 in a laboratory that was at a temperature of 22°C.

The ozone measurement was performed using Gastec detection tubes (No. 18L). The 18L range provides a rapid, fully quantitative analysis of the concentration of ozone in air with an accuracy of ± 25%. The manufacturer states that the minimum detectable concentration as 0.01 ppm. The Gastec tubes were purchased specifically for this work and were marked valid until May 2005. A Gastec multi-stroke gas sampling pump was used in conjunction with the tubes.

The principle of the gas tube operation is described by equation 1 below.

$$2O_3 + C_{16}H_{10}N_2O_2 \rightarrow 2C_8H_5NO_2 + 2O_2 \qquad \text{Eqn (1).}$$

The ozone in air, once sucked up through the tube, bleaches the indigo ($C_{16}H_{10}N_2O_2$, blue) to form isatin ($C_8H_5NO_2$), which is white in colour.

For each position, i.e. 0, 0.5 and 1.0 m from the emitting surface, (at an approximate angle of 90°) and each operational mode, a tube was placed in the pump and held in position manually. The system was left to stabilize for 5 minutes and then 10 pumps (equivalent to 1000 cm^3 volume) were drawn on the hand pump. Each pump lasted an average of 30 seconds. The measurement for each combination of position and operational mode was repeated five times.

Results

The individual results for each tube are shown in Table 18.

Table 18. Individual raw results (ppm) for the Gastec tubes.

Running mode	Order[1]	Replicate results (ppm)					Mean	Actual value[2] (ppm)
		1	2	3	4	5	(ppm)	
Filter in; corona on								
0 m	4th	0.1	0.1	0.1	0.1	0.1	0.1	0.05
0.5 m	5th	0	0	0	0	0	0	0
1.0 m	6th	0	0	0	0	0	0	0
Filter out; corona on								
0 m	3rd	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.025
0.5 m	7th	0	0	0	0	0	0	0
1.0 m	8th	0	0	0	0	0	0	0
Filter in; corona off								
0 m	1st	0	0	0	0	0	0	0
0.5 m	11th	0	0	0	0	0	0	0
1.0 m	12th	0	0	0	0	0	0	0
Filter out; corona off								
0 m	2nd	0	0	0	0	0	0	0
0.5 m	9th	0	0	0	0	0	0	0
1.0 m	10th	0	0	0	0	0	0	0

[1]this shows the order in which the replicates where run.

[2]As 10 pumps were used, the values read from the tubes were halved as per the manufacturers instructions.

Discussion and conclusions

The readings were very small such that the highest readings only coloured the first graduation on the Gastec tube. The highest reading was recorded when the tube was placed at the emitting surface and the filter was in and the korona was on. The next highest reading was recorded with the korona on, but the filter out. All other positions and operational combinations produced no change of colour on the Gastec tube indicating the levels of ozone, if present, were less than 0.01 ppm. The average gap in the Gastec tube through which the air is drawn was 1 mm. The analysis system used is known as active sampling. Five replicate tubes were used for each combination to help account for the potential variability in the positioning of the Gastec tube within the flow of air exiting from the air filtration system.

B: Passive sampling

Tests performed

The tests are were designed to determine whether a significant concentration of ozone accumulated in a confined space in which an AM4 unit operated over an 8 hour period as measured by passive sampling.

The test was performed in a room of approximately 36.75m^3 (3.5m x 3.5m x 3.0m) receiving minimal natural light. Ozone was measure by a number of sampling cards (AFC International Inc, USA).

1. ChromAir ozone cards
2. ChromAir nitrogen cards
3. SafeAir ozone cards
4. SafeAir nitrogen dioxide cards

Nitrogen dioxide is a potential positive interferent beyond 0.3ppm with both ozone sampling cards and so its concentration was also monitored. Average room temperature 19°C. Sample cards were placed randomly on the floor, walls and suspended from the ceiling of the room. The cards were monitored for 8 hours with and without the unit operating. Monitoring was every 15 minutes for the first hour and then after a further 7 hours.

Results

Unit off:

ChromAir ozone cards: 0.08* ppm (0.01 ppm/h)

SafeAir ozone cards: no change detected

Nitrogen Dioxide : none detected

* Lowest recordable concentration = background

Unit on:

ChromAir ozone cards: 0.40 ppm (0.05 ppm/h)

SafeAir ozone cards: qualitative change indicating ozone detected

Nitrogen Dioxide : none detected

Overall ozone levels:

'Unit on' – 'Unit off' values = **0.04 ppm** time weighted average over 8 hour period

Discussion

HSE occupational exposure limit (OEL) for ozone over an 8 hour period is 0.2 ppm and the 15 minute exposure limit is set at 0.4 ppm. The recorded ozone leakage in the experiment was therefore well within (20%) the 8 hour exposure limit.

Claims

1. An apparatus for the cleaning of air comprising a means of generating and retaining ozone or other reactive species within a confined field and a means of drawing a flow of air through said field, wherein said field comprises a concentration of ozone or other reactive species sufficient to effectively oxidise airborne organic material but wherein the concentration of ozone in the cleaned air expelled from said apparatus is less than 0.3ppm.

2. The apparatus of Claim 1 wherein ozone or other reactive species are generated by means of a low power corona discharge unit.

3. The apparatus of Claim 2 wherein the low power corona discharge unit comprises tubular metal gauze electrodes separated by a silica glass dielectric.

4. The apparatus of Claim 3 wherein the low power corona discharge unit is capable of operating at a voltage of less than 5kV and consuming less than 10W.

5. The apparatus of Claim 4 wherein the flow rate of air through the apparatus is in the range 150–500 m^3 per hour

6. The apparatus of any one of Claims 1–5 wherein the field is confined within a partially closed containment means.

7. The apparatus of Claim 6 wherein the containment means has at least one inlet and at least one outlet to allow a through flow of air.

8. The apparatus of Claim 7 wherein said at least one inlet is fitted with at least one filter.

9. The apparatus of Claim 8 wherein said at least one outlet is fitted with at least one filter.

10. The apparatus of Claim 9 wherein the filter fitted to the outlet catalyses the decomposition of ozone to diatomic oxygen, such that the cleaned air having passed through said apparatus contains a concentration of ozone that is less than 0.3 ppm.

11. The apparatus of Claim 10 wherein the filter is an electrostatic filter.

12. The apparatus of any one of Claims 1–11 wherein air is cleaned of micro-organisms.

13. A smoke-removing apparatus according to any of claims 1–10, wherein air is drawn in through one area of a filter assembly and expelled though a second area of the same filter assembly.

14. The apparatus according to Claim 13, wherein the filter assembly comprises two or more filter elements.

15. The apparatus according to Claim 14, wherein the two or more filter elements include at least one electrostatic filter element.

16. A method of cleaning air comprising generating and retaining ozone and /or other reactive species within a confined field, wherein said field comprises a concentration of ozone and / or other reactive species sufficient to effectively oxidise airborne organic material and drawing a flow of air through said field,

such that the cleaned air having passed through said field contains a concentration of ozone of less than 0.3 ppm.

17. The method of claim 16 wherein ozone or other reactive species are generated by means of a low power corona discharge unit

18. The method of either of claims 16 or 17 wherein air also passes through at least one filter after exposure to ozone.

19. The method of Claim 18 wherein the at one filter fitted to the outlet catalyses the decomposition of ozone to diatomic oxygen, such that the cleaned air having passed through said apparatus contains a concentration of ozone that is less than 0.3 ppm.

20. The method of Claim 19 wherein said filter is an electrostatic filter.

21. The method of any of Claims 16–20 wherein air is cleared of viable airborne micro-organisms.

22. The method of any one of Claims 16–20, wherein air is cleaned of smoke particles.

23. The method of Claim 22, wherein air also passes through a filter before exposure to ozone.

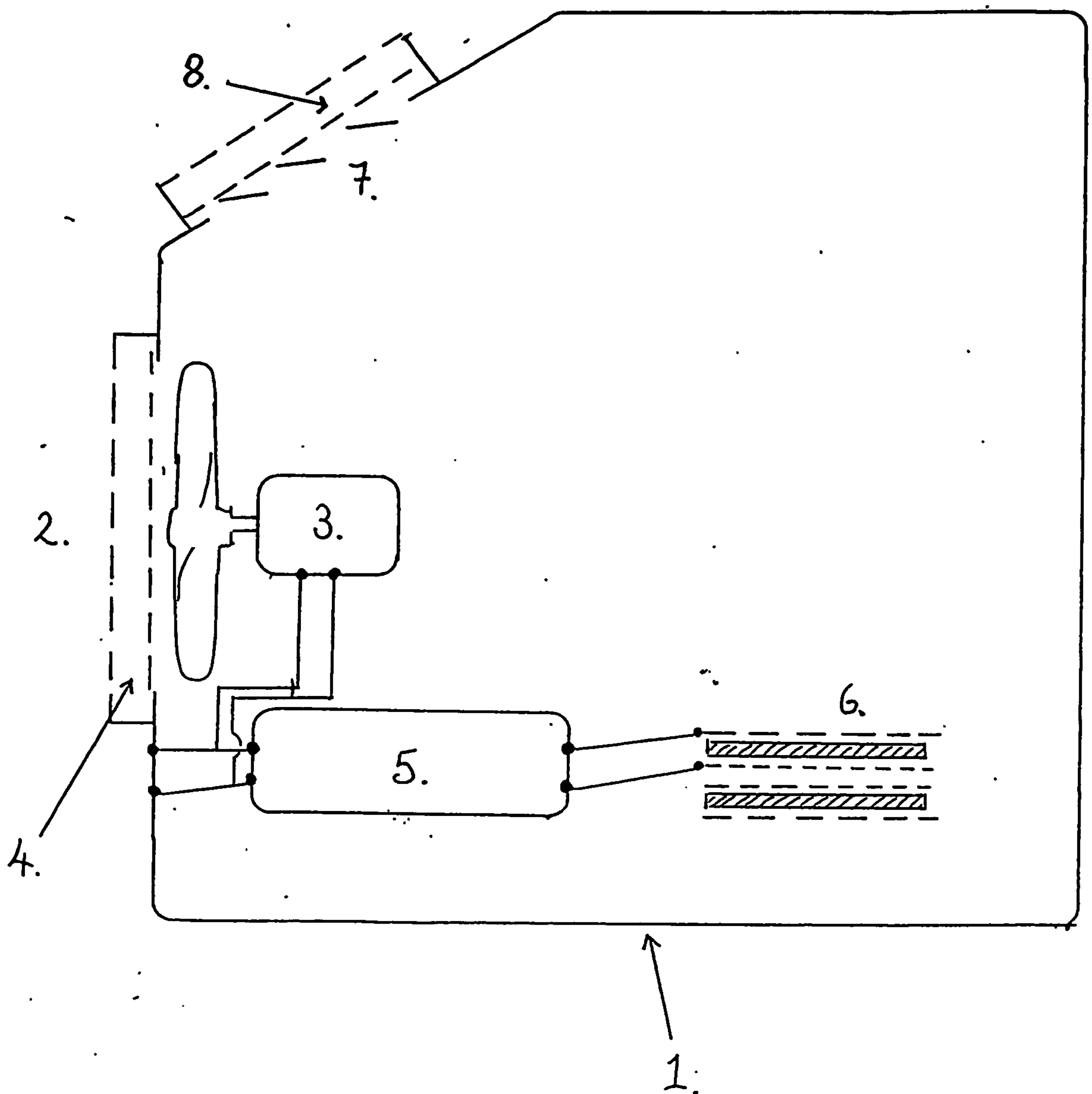

Figure 1

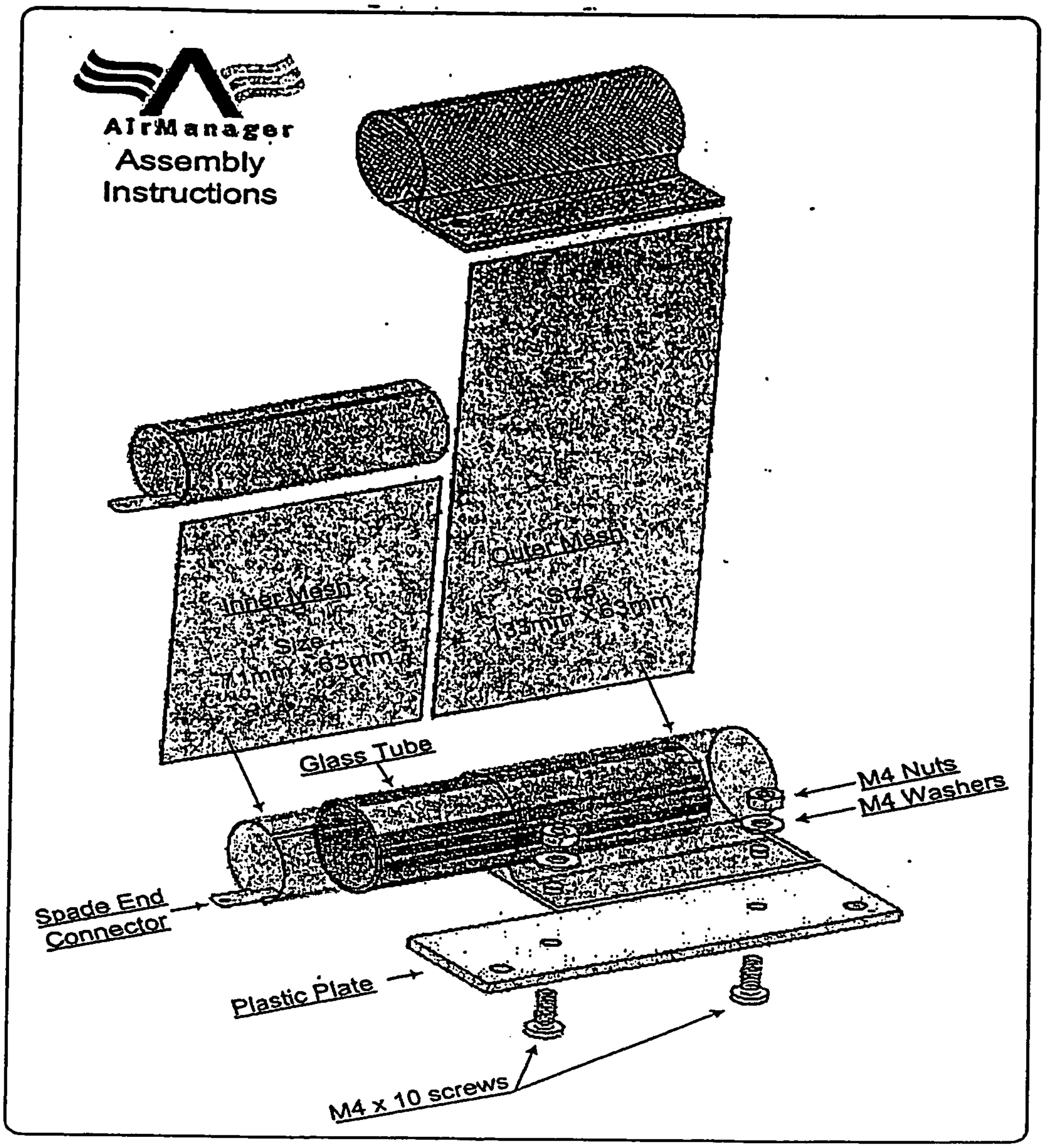
AirManager
Assembly
Instructions
Outer Mesh
Inner Mesh
Glass Tube
M4 Nuts
M4 Washers
Spade End
Connector
Plastic Plate
M4 x 10 screws

Figure 2

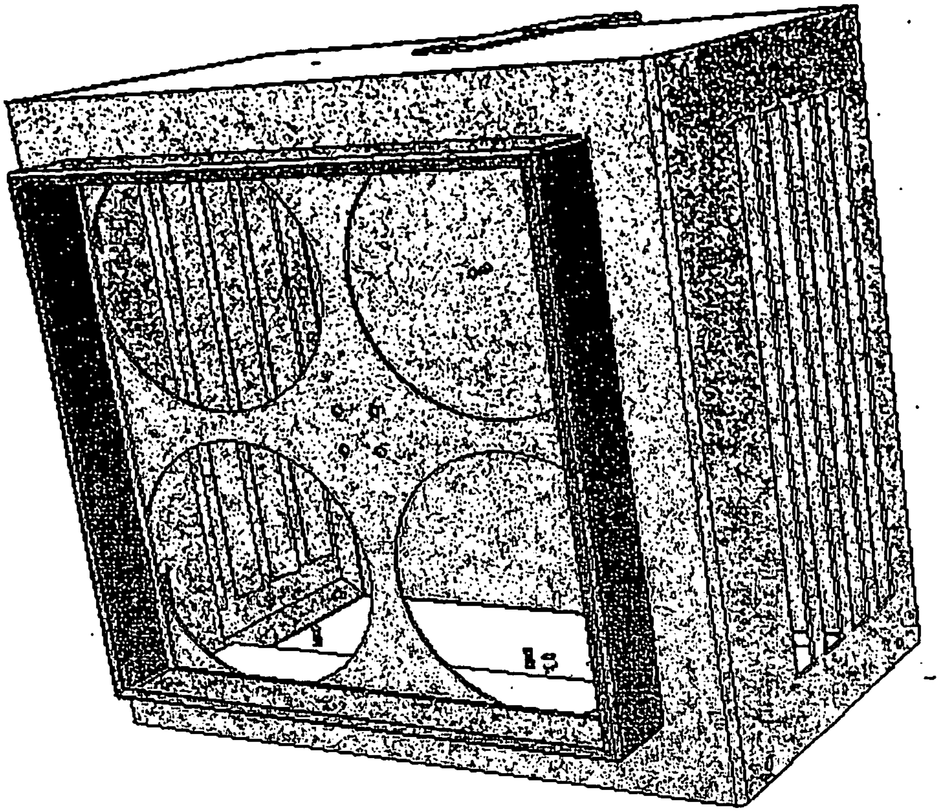

Figure 3

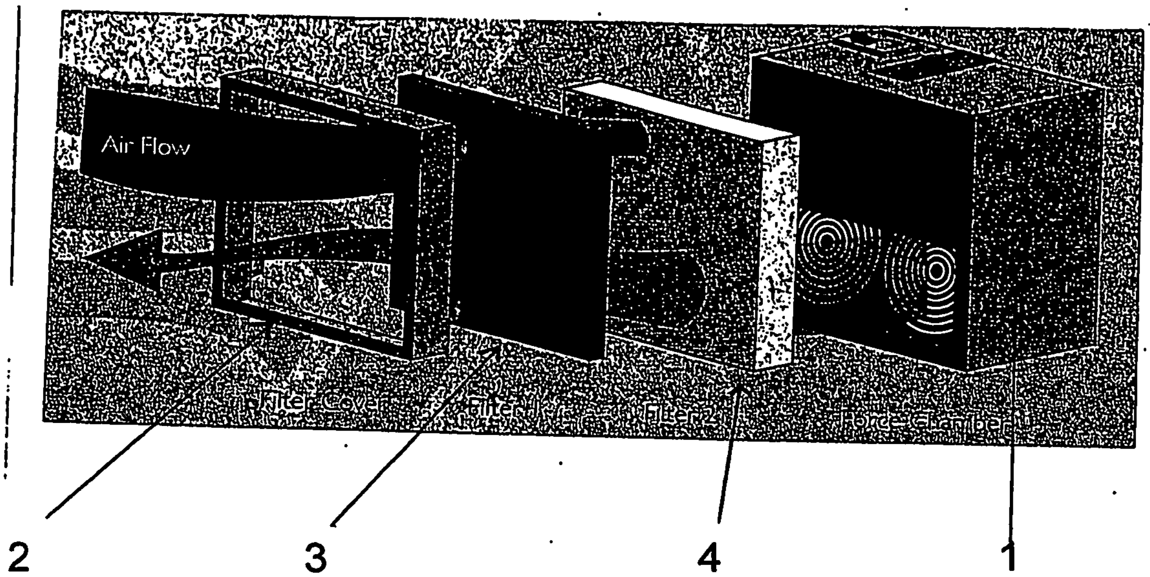

Figure 4